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WITHDRAWN







II. *The Bakerian Lecture. On the Theory of Light and Colours.*  
By Thomas Young, M. D. F. R. S. Professor of Natural Philosophy in the Royal Institution.

Read November 12, 1801.

ALTHOUGH the invention of plausible hypotheses, independent of any connection with experimental observations, can be of very little use in the promotion of natural knowledge; yet the discovery of simple and uniform principles, by which a great number of apparently heterogeneous phenomena are reduced to coherent and universal laws, must ever be allowed to be of considerable importance towards the improvement of the human intellect.

The object of the present dissertation is not so much to propose any opinions which are absolutely new, as to refer some theories, which have been already advanced, to their original inventors, to support them by additional evidence, and to apply them to a great number of diversified facts, which have hitherto been buried in obscurity. Nor is it absolutely necessary in this instance to produce a single new experiment; for of experiments there is already an ample store, which are so much the more unexceptionable, as they must have been conducted without the least partiality for the system by which they will be explained; yet some facts, hitherto unobserved, will be brought forwards, in order to show the perfect agreement of that system with the multifarious phenomena of nature.

The optical observations of NEWTON are yet unrivalled ; and, excepting some casual inaccuracies, they only rise in our estimation, as we compare them with later attempts to improve on them. A further consideration of the colours of thin plates, as they are described in the second book of NEWTON's optics, has converted that prepossession which I before entertained for the undulatory system of light, into a very strong conviction of its truth and sufficiency; a conviction which has been since most strikingly confirmed, by an analysis of the colours of striated substances. The phenomena of thin plates are indeed so singular, that their general complexion is not without great difficulty reconcileable to any theory, however complicated, that has hitherto been applied to them; and some of the principal circumstances have never been explained by the most gratuitous assumptions; but it will appear, that the minutest particulars of these phenomena, are not only perfectly consistent with the theory which will now be detailed, but that they are all the necessary consequences of that theory, without any auxiliary suppositions; and this by inferences so simple, that they become particular corollaries, which scarcely require a distinct enumeration.

A more extensive examination of NEWTON's various writings has shown me, that he was in reality the first that suggested such a theory as I shall endeavour to maintain; that his own opinions varied less from this theory than is now almost universally supposed; and that a variety of arguments have been advanced, as if to confute him, which may be found nearly in a similar form in his own works; and this by no less a mathematician than LEONARD EULER, whose system of light, as far as it is worthy of notice, either was, or might have been,

wholly borrowed from NEWTON, HOOKE, HUYGENS, and MALE-BRANCHE.

Those who are attached, as they may be with the greatest justice, to every doctrine which is stamped with the NEWTONIAN approbation, will probably be disposed to bestow on these considerations so much the more of their attention, as they appear to coincide more nearly with NEWTON's own opinions. For this reason, after having briefly stated each particular position of my theory, I shall collect, from NEWTON's various writings, such passages as seem to be the most favourable to its admission; and, although I shall quote some papers which may be thought to have been partly retracted at the publication of the optics, yet I shall borrow nothing from them that can be supposed to militate against his maturer judgment.

#### HYPOTHESIS I.

*A luminiferous Ether pervades the Universe, rare and elastic in a high degree.*

#### *Passages from NEWTON.*

“ The hypothesis certainly has a much greater affinity with “ his own,” that is, Dr. Hooke's, “ hypothesis, than he seems “ to be aware of; the vibrations of the ether being as useful and “ necessary in this, as in his.” (Phil. Trans. Vol. VII. p. 5087. Abr. Vol. I. p. 145. Nov. 1672.)

“ To proceed to the hypothesis: first, it is to be supposed “ therein, that there is an ethereal medium, much of the same “ constitution with air, but far rarer, subtler, and more strongly “ elastic.—It is not to be supposed, that this medium is one “ uniform matter, but compounded, partly of the main phleg- “ matic body of ether, partly of other various ethereal spirits,

“ much after the manner that air is compounded of the phlegmatic body of air, intermixed with various vapours and exhalations: for the electric and magnetic effluvia, and gravitating principle, seem to argue such variety.” (BIRCH: Hist. of R. S. Vol. III. p. 249. Dec. 1675.)

“ Is not the heat (of the warm room) conveyed through the vacuum by the vibrations of a much subtler medium than air? —And is not this medium the same with that medium by which light is refracted and reflected, and by whose vibrations light communicates heat to bodies, and is put into fits of easy reflection, and easy transmission? And do not the vibrations of this inedium in hot bodies, contribute to the intenseness and duration of their heat? And do not hot bodies communicate their heat to contiguous cold ones, by the vibrations of this medium propagated from them into the cold ones? And is not this medium exceedingly more rare and subtile than the air, and exceedingly more elastic and active? And doth it not readily pervade all bodies? And is it not, by its elastic force, expanded through all the heavens?—May not planets and comets, and all gross bodies, perform their motions in this ethereal medium?—And may not its resistance be so small, as to be inconsiderable? For instance, if this ether (for so I will call it) should be supposed 700,000 times more elastic than our air, and above 700,000 times more rare, its resistance would be about 600,000000 times less than that of water. And so small a resistance would scarce make any sensible alteration in the motions of the planets, in ten thousand years. If any one would ask how a medium can be so rare, let him tell me—how an electric body can by friction emit an exhalation so rare and subtile, and yet so potent?—And how the

" effluvia of a magnet can pass through a plate of glass, without resistance, and yet turn a magnetic needle beyond the " glass ?" (Optics, Qu. 18, 22.)

## HYPOTHESIS II.

*Undulations are excited in this Ether whenever a Body becomes luminous.*

*Scholium.* I use the word undulation, in preference to vibration, because vibration is generally understood as implying a motion which is continued alternately backwards and forwards, by a combination of the momentum of the body with an accelerating force, and which is naturally more or less permanent ; but an undulation is supposed to consist in a vibratory motion, transmitted successively through different parts of a medium, without any tendency in each particle to continue its motion, except in consequence of the transmission of succeeding undulations, from a distinct vibrating body ; as, in the air, the vibrations of a chord produce the undulations constituting sound.

*Passages from NEWTON.*

" Were I to assume an hypothesis, it should be this, if proposed more generally, so as not to determine what light is, " further than that it is something or other capable of exciting " vibrations in the ether ; for thus it will become so general and " comprehensive of other hypotheses, as to leave little room for " new ones to be invented." (BIRCH. Vol. III. p. 249. Dec. 1675.)

" In the second place, it is to be supposed, that the ether is a " vibrating medium like air, only the vibrations far more swift " and minute ; those of air, made by a man's ordinary voice, " succeeding one another at more than half a foot, or a foot

“ distance; but those of ether at a less distance than the hundred thousandth part of an inch. And, as in air the vibrations are some larger than others, but yet all equally swift, (for in a ring of bells the sound of every tone is heard at two or three miles distance, in the same order that the bells are struck,) so, I suppose, the ethereal vibrations differ in big- ness, but not in swiftness. Now, these vibrations, beside their use in reflection and refraction, may be supposed the chief means by which the parts of fermenting or putrifying substances, fluid liquors, or melted, burning, or other hot bodies, continue in motion.” (BIRCH Vol. III. p. 251. Dec. 1675.)

“ When a ray of light falls upon the surface of any pellucid body, and is there refracted or reflected, may not waves of vibrations, or tremors, be thereby excited in the refracting or reflecting medium?—And are not these vibrations propagated from the point of incidence to great distances? And do they not overtake the rays of light, and by overtaking them successively, do not they put them into the fits of easy reflection and easy transmission described above?” (Optics. Qu. 17.)

“ Light is in fits of easy reflection and easy transmission, before its incidence on transparent bodies. And probably it is put into such fits at its first emission from luminous bodies, and continues in them during all its progress.” (Optics. Second Book. Part III. Prop. 13.)

## HYPOTHESIS III.

*The Sensation of different Colours depends on the different frequency of Vibrations, excited by Light in the Retina.*

*Passages from NEWTON.*

“ The objector's hypothesis, as to the fundamental part of it,  
“ is not against me. That fundamental supposition is, that the  
“ parts of bodies, when briskly agitated, do excite vibrations in  
“ the ether, which are propagated every way from those bodies  
“ in straight lines, and cause a sensation of light by beating  
“ and dashing against the bottom of the eye, something after  
“ the manner that vibrations in the air cause a sensation of  
“ sound by beating against the organs of hearing. Now, the  
“ most free and natural application of this hypothesis to the  
“ solution of phenomena, I take to be this: that the agitated  
“ parts of bodies, according to their several sizes, figures, and  
“ motions, do excite vibrations in the ether of various depths  
“ or bignesses, which, being promiscuously propagated through  
“ that medium to our eyes, effect in us a sensation of light of a  
“ white colour; but if by any means those of unequal bignesses  
“ be separated from one another, the largest beget a sensation  
“ of a red colour, the least or shortest of a deep violet, and  
“ the intermediate ones of intermediate colours; much after  
“ the manner that bodies, according to their several sizes,  
“ shapes, and motions, excite vibrations in the air of various  
“ bignesses, which, according to those bignesses, make several  
“ tones in sound: that the largest vibrations are best able to  
“ overcome the resistance of a refracting superficies, and so  
“ break through it with least refraction; whence the vibrations

“ of several bignesses, that is, the rays of several colours, which  
“ are blended together in light, must be parted from one an-  
“ other by refraction, and so cause the phenomena of prisms,  
“ and other refracting substances; and that it depends on the  
“ thickness of a thin transparent plate or bubble, whether a  
“ vibration shall be reflected at its further superficies, or trans-  
“ mitted; so that, according to the number of vibrations, inter-  
“ ceding the two superficies, they may be reflected or transmitted  
“ for many successive thicknesses. And, since the vibrations  
“ which make blue and violet, are supposed shorter than those  
“ which make red and yellow, they must be reflected at a less  
“ thickness of the plate: which is sufficient to explicate all the  
“ ordinary phenomena of those plates or bubbles, and also of  
“ all natural bodies, whose parts are like so many fragments of  
“ such plates. These seem to be the most plain, genuine, and  
“ necessary conditions of this hypothesis. And they agree so  
“ justly with my theory, that if the animadversor think fit to  
“ apply them, he need not, on that account, apprehend a divorce  
“ from it. But yet, how he will defend it from other difficulties,  
“ I know not.” (Phil. Trans. Vol. VII. p. 5088. Abr. Vol. I.  
p. 145. Nov. 1672.)

“ To explain colours, I suppose, that as bodies of various  
“ sizes, densities, or sensations, do by percussion or other  
“ action excite sounds of various tones, and consequently vi-  
“ brations in the air of different bigness; so the rays of light,  
“ by impinging on the stiff refracting superficies, excite vibra-  
“ tions in the ether,—of various bigness; the biggest, strongest,  
“ or most potent rays, the largest vibrations; and others shorter,  
“ according to their bigness, strength, or power: and therefore  
“ the ends of the capillamenta of the optic nerve, which pave

“ or face the retina, being such refracting superficies, when the rays impinge upon them, they must there excite these vibrations, which vibrations (like those of sound in a trunk or trumpet) will run along the aqueous pores or crystalline pith of the capillamenta, through the optic nerves, into the sensorium;—and there, I suppose, affect the sense with various colours, according to their bigness and mixture; the biggest with the strongest colours, reds and yellows; the least with the weakest, blues and violets; the middle with green; and a confusion of all with white, much after the manner that, in the sense of hearing, nature makes use of aerial vibrations of several bignesses, to generate sounds of divers tones; for the analogy of nature is to be observed.” (BIRCH Vol. III. p. 262. Dec. 1675.)

“ Considering the lastingness of the motions excited in the bottom of the eye by light, are they not of a vibrating nature? —Do not the most refrangible rays excite the shortest vibrations,—the least refrangible the largest? May not the harmony and discord of colours arise from the proportions of the vibrations propagated through the fibres of the optic nerve into the brain, as the harmony and discord of sounds arise from the proportions of the vibrations of the air?” (Optics, Qu. 16, 13, 14.)

*Scholium.* Since, for the reason here assigned by NEWTON, it is probable that the motion of the retina is rather of a vibratory than of an undulatory nature, the frequency of the vibrations must be dependent on the constitution of this substance. Now, as it is almost impossible to conceive each sensitive point of the retina to contain an infinite number of particles, each capable of vibrating in perfect unison with every possible undulation, it

becomes necessary to suppose the number limited, for instance, to the three principal colours, red, yellow, and blue, of which the undulations are related in magnitude nearly as the numbers 8, 7, and 6; and that each of the particles is capable of being put in motion less or more forcibly, by undulations differing less or more from a perfect unison; for instance, the undulations of green light being nearly in the ratio of  $6\frac{1}{2}$ , will affect equally the particles in unison with yellow and blue, and produce the same effect as a light composed of those two species: and each sensitive filament of the nerve may consist of three portions, one for each principal colour. Allowing this statement, it appears that any attempt to produce a musical effect from colours, must be unsuccessful, or at least that nothing more than a very simple melody could be imitated by them; for the period, which in fact constitutes the harmony of any concord, being a multiple of the periods of the single undulations, would in this case be wholly without the limits of sympathy of the retina, and would lose its effect; in the same manner as the harmony of a third or a fourth is destroyed, by depressing it to the lowest notes of the audible scale. In hearing, there seems to be no permanent vibration of any part of the organ.

## HYPOTHESIS IV.

*All material Bodies have an Attraction for the ethereal Medium, by means of which it is accumulated within their Substance, and for a small Distance around them, in a State of greater Density, but not of greater Elasticity.*

It has been shewn, that the three former hypotheses, which may be called essential, are literally parts of the more complicated NEWTONIAN system. This fourth hypothesis differs perhaps

in some degree from any that have been proposed by former authors, and is diametrically opposite to that of NEWTON; but, both being in themselves equally probable, the opposition is merely accidental; and it is only to be inquired which is the best capable of explaining the phenomena. Other suppositions might perhaps be substituted for this, and therefore I do not consider it as fundamental, yet it appears to be the simplest and best of any that have occurred to me.

PROPOSITION I.

*All Impulses are propagated in a homogeneous elastic Medium with an equable Velocity.*

Every experiment relative to sound coincides with the observation already quoted from NEWTON, that all undulations are propagated through the air with equal velocity; and this is further confirmed by calculations. (LAGRANGE. *Misc. Taur.* Vol. I. p. 91. Also, much more concisely, in my *Syllabus of a course of Lectures on Natural and Experimental Philosophy*, about to be published. Article 289.) If the impulse be so great as materially to disturb the density of the medium, it will be no longer homogeneous; but, as far as concerns our senses, the quantity of motion may be considered as infinitely small. It is surprising that EULER, although aware of the matter of fact, should still have maintained, that the more frequent undulations are more rapidly propagated. (*Theor. mus. and Conject. phys.*) It is possible, that the actual velocity of the particles of the luminiferous ether may bear a much less proportion to the velocity of the undulations than in sound; for light may be excited by the motion of a body moving at the rate of only one mile in the time that light moves a hundred millions.

*Scholium 1.* It has been demonstrated, that in different mediums the velocity varies in the subduplicate ratio of the force directly, and of the density inversely. (Misc. Taur. Vol. I. p. 91. YOUNG's Syllabus. Art. 294.)

*Scholium 2.* It is obvious, from the phenomena of elastic bodies and of sounds, that the undulations may cross each other without interruption. But there is no necessity that the various colours of white light should intermix their undulations; for, supposing the vibrations of the retina to continue but a five hundredth of a second after their excitement, a million undulations of each of a million colours may arrive in distinct succession within this interval of time, and produce the same sensible effect, as if all the colours arrived precisely at the same instant.

#### PROPOSITION II.

*An Undulation conceived to originate from the Vibration of a single Particle, must expand through a homogeneous Medium in a spherical Form, but with different quantities of Motion in different Parts.*

For, since every impulse, considered as positive or negative, is propagated with a constant velocity, each part of the undulation must in equal times have past through equal distances from the vibrating point. And, supposing the vibrating particle, in the course of its motion, to proceed forwards to a small distance in a given direction, the principal strength of the undulation will naturally be straight before it; behind it, the motion will be equal, in a contrary direction; and, at right angles to the line of vibration, the undulation will be evanescent.

Now, in order that such an undulation may continue its progress to any considerable distance, there must be in each part of it, a tendency to preserve its own motion in a right line from

the centre; for, if the excess of force at any part were communicated to the neighbouring particles, there can be no reason why it should not very soon be equalised throughout, or, in other words, become wholly extinct, since the motions in contrary directions would naturally destroy each other. The origin of sound from the vibration of a chord is evidently of this nature; on the contrary, in a circular wave of water, every part is at the same instant either elevated or depressed. It may be difficult to show mathematically, the mode in which this inequality of force is preserved; but the inference from the matter of fact, appears to be unavoidable; and, while the science of hydrodynamics is so imperfect that we cannot even solve the simple problem of the time required to empty a vessel by a given aperture, it cannot be expected that we should be able to account perfectly for so complicated a series of phenomena, as those of elastic fluids. The theory of HUYGENS indeed explains the circumstance in a manner tolerably satisfactory: he supposes every particle of the medium to propagate a distinct undulation in all directions; and that the general effect is only perceptible where a portion of each undulation conspires in direction at the same instant; and it is easy to show that such a general undulation would in all cases proceed rectilinearly, with proportionate force; but, upon this supposition, it seems to follow, that a greater quantity of force must be lost by the divergence of the partial undulations, than appears to be consistent with the propagation of the effect to any considerable distance. Yet it is obvious, that some such limitation of the motion must naturally be expected to take place; for, if the intensity of the motion of any particular part, instead of continuing to be propagated straight forwards, were supposed to affect the intensity of a neighbouring part of the undulation, an

impulse must then have travelled from an internal to an external circle in an oblique direction, in the same time as in the direction of the radius, and consequently with a greater velocity; against the first proposition. In the case of water, the velocity is by no means so rigidly limited as in that of an elastic medium. Yet it is not necessary to suppose, nor is it indeed probable, that there is absolutely not the least lateral communication of the force of the undulation, but that, in highly elastic mediums, this communication is almost insensible. In the air, if a chord be perfectly insulated, so as to propagate exactly such vibrations as have been described, they will in fact be much less forcible than if the chord be placed in the neighbourhood of a sounding board, and probably in some measure because of this lateral communication of motions of an opposite tendency. And the different intensity of different parts of the same circular undulation may be observed, by holding a common tuning fork at arm's length, while sounding, and turning it, from a plane directed to the ear, into a position perpendicular to that plane.

## PROPOSITION III.

*A Portion of a spherical Undulation, admitted through an Aperture into a quiescent Medium, will proceed to be further propagated rectilinearly in concentric Superficies, terminated laterally by weak and irregular Portions of newly diverging Undulations.*

At the instant of admission, the circumference of each of the undulations may be supposed to generate a partial undulation, filling up the nascent angle between the radii and the surfaces terminating the medium; but no sensible addition will be made

to its strength by a divergence of motion from any other parts of the undulation, for want of a coincidence in time, as has already been explained with respect to the various force of a spherical undulation. If indeed the aperture bear but a small proportion to the breadth of an undulation, the newly generated undulation may nearly absorb the whole force of the portion admitted; and this is the case considered by NEWTON in the Principia. But no experiment can be made under these circumstances with light, on account of the minuteness of its undulations, and the interference of inflection; and yet some faint radiations do actually diverge beyond any probable limits of inflection, rendering the margin of the aperture distinctly visible in all directions; these are attributed by NEWTON to some unknown cause, distinct from inflection; (*Optics*, Third Book, Obs. 5.) and they fully answer the description of this proposition.

Let the concentric lines in Fig. 1. (Plate I.) represent the contemporaneous situation of similar parts of a number of successive undulations diverging from the point A; they will also represent the successive situations of each individual undulation: let the force of each undulation be represented by the breadth of the line, and let the cone of light ABC be admitted through the aperture BC; then the principal undulations will proceed in a rectilinear direction towards GH, and the faint radiations on each side will diverge from B and C as centres, without receiving any additional force from any intermediate point D of the undulation, on account of the inequality of the lines DE and DF. But, if we allow some little lateral divergence from the extremities of the undulations, it must diminish their force, without adding materially to that of the dissipated light; and their

termination, instead of the right line BG, will assume the form CH; since the loss of force must be more considerable near to C than at greater distances. This line corresponds with the boundary of the shadow in NEWTON's first observation, Fig. 1; and it is much more probable that such a dissipation of light was the cause of the increase of the shadow in that observation, than that it was owing to the action of the inflecting atmosphere, which must have extended a thirtieth of an inch each way in order to produce it; especially when it is considered that the shadow was not diminished by surrounding the hair with a denser medium than air, which must in all probability have weakened and contracted its inflecting atmosphere. In other circumstances, the lateral divergence might appear to increase, instead of diminishing, the breadth of the beam.

As the subject of this proposition has always been esteemed the most difficult part of the undulatory system, it will be proper to examine here the objections which NEWTON has grounded upon it.

"To me, the fundamental supposition itself seems impossible; "namely, that the waves or vibrations of any fluid can, like the "rays of light, be propagated in straight lines, without a continual and very extravagant spreading and bending every way into the quiescent medium, where they are terminated "by it. I mistake, if there be not both experiment and demonstration to the contrary." (Phil. Trans. VII. 5089, Abr. I. 146. Nov. 1672.)

"Motus omnis per fluidum propagatus divergit a recto trahite in spatia immota."

"Quoniam medium ibi," in the middle of an undulation

admitted, “densius est, quam in spatiis hinc inde, dilatabit sese  
“tam versus spatia utrinque sita, quam versus pulsuum rariora  
“intervalla; eoque pacto—pulsus eadem *ferē* celeritate sese in  
“medii partes quiescentes hinc inde relaxare debent;—ideoque  
“spatium totum occupabunt.—Hoc experimur in sonis.” (Prin-  
cip. Lib. II. Prop. 42.

“Are not all hypotheses erroneous, in which light is supposed  
“to consist in pression or motion, propagated through a fluid  
“medium?—If it consisted in pression or motion, propagated  
“either in an instant, or in time, it would bend into the shadow.  
“For pression or motion cannot be propagated in a fluid in  
“right lines beyond an obstacle which stops part of the motion,  
“but will bend and spread every way into the quiescent medium  
“which lies beyond the obstacle.—The waves on the surface of  
“stagnating water, passing by the sides of a broad obstacle  
“which stops part of them, bend afterwards, and dilate them-  
“selves gradually into the quiet water behind the obstacle.  
“The waves, pulses, or vibrations of the air, wherein sounds  
“consist, bend manifestly, though not so much as the waves  
“of water. For a bell or a cannon may be heard beyond a  
“hill, which intercepts the sight of the sounding body; and  
“sounds are propagated as readily through crooked pipes as  
“straight ones. But light is never known to follow crooked  
“passages, nor to bend into the shadow. For the fixed stars,  
“by the interposition of any of the planets, cease to be seen.  
“And so do the parts of the sun, by the interposition of the  
“moon, Mercury, or Venus. The rays which pass very near  
“to the edges of any body, are bent a little by the action of the  
“body;—but this bending is not towards but from the shadow,

“ and is performed only in the passage of the ray by the body, “ and at a very small distance from it. So soon as the ray is “ past the body, it goes right on.” (Optics, Qu. 28.)

Now the proposition quoted from the Principia does not directly contradict this proposition; for it does not assert that such a motion must diverge equally in all directions; neither can it with truth be maintained, that the parts of an elastic medium communicating any motion, must propagate that motion equally in all directions. (Phil. Trans. for 1800. p. 109—112.) All that can be inferred by reasoning is, that the marginal parts of the undulation must be somewhat weakened, and that there must be a faint divergence in every direction; but whether either of these effects might be of sufficient magnitude to be sensible, could not have been inferred from argument, if the affirmative had not been rendered probable by experiment.

As to the analogy with other fluids, the most natural inference from it is this: “ The waves of the air, wherein sounds consist, “ bend manifestly, though not so much as the waves of water;” water being an inelastic, and air a moderately elastic medium; but ether being most highly elastic, its waves bend very far less than those of the air, and therefore almost imperceptibly. Sounds are propagated through crooked passages, because their sides are capable of reflecting sound, just as light would be propagated through a bent tube, if perfectly polished within.

The light of a star is by far too weak to produce, by its faint divergence, any visible illumination of the margin of a planet eclipsing it; and the interception of the sun’s light by the moon, is as foreign to the question, as the statement of inflection is inaccurate.

To the argument adduced by HUYGENS, in favour of the

rectilinear propagation of undulations, NEWTON has made no reply; perhaps because of his own misconception of the nature of the motions of elastic mediums, as dependent on a peculiar law of vibration, which has been corrected by later mathematicians. (Phil. Trans. for 1800, p. 116.) On the whole, it is presumed, that this proposition may be safely admitted, as perfectly consistent with analogy and with experiment.

#### PROPOSITION IV.

*When an Undulation arrives at a Surface which is the Limit of Mediums of different Densities, a partial Reflection takes place, proportionate in Force to the Difference of the Densities.*

This may be illustrated, if not demonstrated, by the analogy of elastic bodies of different sizes. " If a smaller elastic body " strikes against a larger one, it is well known that the smaller " is reflected more or less powerfully, according to the difference of their magnitudes: thus, there is always a reflection " when the rays of light pass from a rarer to a denser stratum " of ether; and frequently an echo when a sound strikes " against a cloud. A greater body striking a smaller one, propels it, without losing all its motion: thus, the particles of a denser stratum of ether, do not impart the whole of their motion to a rarer, but, in their effort to proceed, they are recalled by the attraction of the refracting substance with equal force; and thus a reflection is always secondarily produced, when the rays of light pass from a denser to a rarer stratum." (Phil. Trans. for 1800, p. 127.) But it is not absolutely necessary to suppose an attraction in the latter case, since the effort to proceed would be propagated backwards without it, and the undulation would be reversed, a rarefaction

returning in place of a condensation; and this will perhaps be found most consistent with the phenomena.

## PROPOSITION V.

*When an Undulation is transmitted through a Surface terminating different Mediums, it proceeds in such a Direction, that the Sines of the Angles of Incidence and Refraction are in the constant Ratio of the Velocity of Propagation in the two Mediums.*

(BARROW, Lect. Opt. II. p. 4. HUYGENS, *de la Lum.* cap. 3. EULER, *Conj. Phys.* Phil. Trans. for 1800, p. 128. YOUNG's Syllabus. Art. 382.)

*Corollary 1.* The same demonstrations prove the equality of the angles of reflection and incidence.

*Corollary 2.* It appears from experiments on the refraction of condensed air, that the ratio of the difference of the sines varies simply as the density. Hence it follows, by Schol. I. Prop. I. that the excess of the density of the ethereal medium is in the duplicate ratio of the density of the air; each particle cooperating with its neighbours in attracting a greater portion of it.

## PROPOSITION VI.

*When an Undulation falls on the Surface of a rarer Medium, so obliquely that it cannot be regularly refracted, it is totally reflected, at an Angle equal to that of its Incidence.*

(Phil. Trans. for 1800, p. 128.)

*Corollary.* This phenomenon tends to prove the gradual increase and diminution of density at the surface terminating two media, as supposed in HYPOTHESIS IV; although HUYGENS has attempted to explain it somewhat differently.

## PROPOSITION VII.

*If equidistant Undulations be supposed to pass through a Medium, of which the Parts are susceptible of permanent Vibrations somewhat slower than the Undulations, their Velocity will be somewhat lessened by this vibratory Tendency; and, in the same Medium, the more, as the Undulations are more frequent.*

For, as often as the state of the undulation requires a change in the actual motion of the particle which transmits it, that change will be retarded by the propensity of the particle to continue its motion somewhat longer: and this retardation will be more frequent, and more considerable, as the difference between the periods of the undulation and of the natural vibration is greater.

*Corollary.* It was long an established opinion, that heat consists in vibrations of the particles of bodies, and is capable of being transmitted by undulations through an apparent vacuum. (NEWT. Opt. Qu. 18.) This opinion has been of late very much abandoned. Count RUMFORD, Professor PICTET, and Mr. DAVY, are almost the only authors who have appeared to favour it; but it seems to have been rejected without any good grounds, and will probably very soon recover its popularity.

Let us suppose that these vibrations are less frequent than those of light; all bodies therefore are liable to permanent vibrations slower than those of light; and indeed almost all are liable to luminous vibrations, either when in a state of ignition, or in the circumstances of solar phosphori; but much less easily, and in a much less degree, than to the vibrations of heat. It will follow from these suppositions, that the more frequent luminous undulations will be more retarded than the less frequent; and

consequently, that blue light will be more refrangible than red, and radiant heat least of all ; a consequence which coincides exactly with the highly interesting experiments of Dr. HERSCHEL. (Phil. Trans. for 1800. p. 284.) It may also be easily conceived, that the actual existence of a state of slower vibration may tend still more to retard the more frequent undulations, and that the refractive power of solid bodies may be sensibly increased by an increase of temperature, as it actually appears to have been in EULER's experiments. (Acad. de Berlin. 1762. p. 328.)

*Scholium.* If, notwithstanding, this proposition should appear to be insufficiently demonstrated, it must be allowed to be at least equally explanatory of the phenomena with any thing that can be advanced on the other side, from the doctrine of projectiles ; since a supposed accelerating force must act in some other proportion than that of the bulk of the particles ; and, if we call this an elective attraction, it is only veiling under a chemical term, our incapacity of assigning a mechanical cause. Mr. SHORT, when he found by observation the equality of the velocity of light of all colours, felt the objection so forcibly, that he immediately drew an inference from it in favour of the undulatory system. It is assumed in the proposition, that when light is dispersed by refraction, the corpuscles of the refracting substance are in a state of actual alternate motion, and contribute to its transmission ; but it must be confessed, that we cannot at present form a very decided and accurate conception of the forces concerned in maintaining these corpuscular vibrations.

## PROPOSITION VIII.

*When two Undulations, from different Origins, coincide either perfectly or very nearly in Direction, their joint effect is a Combination of the Motions belonging to each.*

Since every particle of the medium is affected by each undulation, wherever the directions coincide, the undulations can proceed no otherwise than by uniting their motions, so that the joint motion may be the sum or difference of the separate motions, accordingly as similar or dissimilar parts of the undulations are coincident.

I have, on a former occasion, insisted at large on the application of this principle to harmonics; (Phil. Trans. for 1800. p. 130.) and it will appear to be of still more extensive utility in explaining the phenomena of colours. The undulations which are now to be compared are those of equal frequency. When the two series coincide exactly in point of time, it is obvious that the united velocity of the particular motions must be greatest, and, in effect at least, double the separate velocities; and also, that it must be smallest, and if the undulations are of equal strength, totally destroyed, when the time of the greatest direct motion belonging to one undulation coincides with that of the greatest retrograde motion of the other. In intermediate states, the joint undulation will be of intermediate strength; but by what laws this intermediate strength must vary, cannot be determined without further data. It is well known that a similar cause produces in sound, that effect which is called a beat; two series of undulations of nearly equal magnitude co-operating and destroying each other alternately, as they coincide

more or less perfectly in the times of performing their respective motions.

COROLLARY I. *Of the Colours of striated Surfaces.*

BOYLE appears to have been the first that observed the colours of scratches on polished surfaces. NEWTON has not noticed them. MAZEAS and Mr. BROUHAM have made some experiments on the subject, yet without deriving any satisfactory conclusion. But all the varieties of these colours are very easily deduced from this proposition.

Let there be in a given plane two reflecting points very near each other, and let the plane be so situated that the reflected image of a luminous object seen in it may appear to coincide with the points; then it is obvious that the length of the incident and reflected ray, taken together, is equal with respect to both points, considering them as capable of reflecting in all directions. Let one of the points be now depressed below the given plane; then the whole path of the light reflected from it, will be lengthened by a line which is to the depression of the point as twice the cosine of incidence to the radius. Fig. 2.

If, therefore, equal undulations of given dimensions be reflected from two points, situated near enough to appear to the eye but as one, wherever this line is equal to half the breadth of a whole undulation, the reflection from the depressed point will so interfere with the reflection from the fixed point, that the progressive motion of the one will coincide with the retrograde motion of the other, and they will both be destroyed; but, when this line is equal to the whole breadth of an undulation, the effect will be doubled; and when to a breadth and a half, again destroyed; and thus for a considerable number of alternations; and, if the reflected undulations be of different kinds, they will

be variously affected, according to their proportions to the various length of the line which is the difference between the lengths of their two paths, and which may be denominated the interval of retardation.

In order that the effect may be the more perceptible, a number of pairs of points must be united into two parallel lines; and, if several such pairs of lines be placed near each other, they will facilitate the observation. If one of the lines be made to revolve round the other as an axis, the depression below the given plane will be as the sine of the inclination; and, while the eye and luminous object remain fixed, the difference of the length of the paths will vary as this sine.

The best subjects for the experiment are Mr. COVENTRY's exquisite micrometers; such of them as consist of parallel lines drawn on glass, at the distance of one five hundredth of an inch, are the most convenient. Each of these lines appears under a microscope to consist of two or more finer lines, exactly parallel, and at the distance of somewhat more than a twentieth of that of the adjacent lines. I placed one of these so as to reflect the sun's light at an angle of  $45^\circ$ , and fixed it in such a manner, that while it revolved round one of the lines as an axis, I could measure its angular motion; and I found, that the brightest red colour occurred at the inclinations  $10\frac{1}{4}^\circ$ ,  $20\frac{3}{4}^\circ$ ,  $32^\circ$ , and  $45^\circ$ ; of which the sines are as the numbers 1, 2, 3, and 4. At all other angles also, when the sun's light was reflected from the surface, the colour vanished with the inclination, and was equal at equal inclinations on either side.

This experiment affords a very strong confirmation of the theory. It is impossible to deduce any explanation of it from any hypothesis hitherto advanced; and I believe it would be

difficult to invent any other that would account for it. There is a striking analogy between this separation of colours, and the production of a musical note by successive echoes from equidistant iron palisades ; which I have found to correspond pretty accurately with the known velocity of sound, and the distances of the surfaces.

It is not improbable that the colours of the integuments of some insects, and of some other natural bodies, exhibiting in different lights the most beautiful versatility, may be found to be of this description, and not to be derived from thin plates. In some cases, a single scratch or furrow may produce similar effects, by the reflection of its opposite edges.

COROLLARY II. *Of the Colours of thin Plates:*

When a beam of light falls on two parallel refracting surfaces, the partial reflections coincide perfectly in direction ; and, in this case, the interval of retardation, taken between the surfaces, is to their distance as twice the cosine of the angle of refraction to the radius. For, in Fig. 3, drawing AB and CD perpendicular to the rays, the times of passing through BC and AD will be equal, and DE will be half the interval of retardation; but DE is to CE as the sine of DCE to the radius. Hence, that DE may be constant, or that the same colour may be reflected, the thickness CE must vary as the secant of the angle of refraction CED : which agrees exactly with NEWTON's experiments ; for the correction is perfectly inconsiderable.

Let the medium between the surfaces be rarer than the surrounding mediums ; then the impulse reflected at the second surface, meeting a subsequent undulation at the first, will render the particles of the rarer medium capable of wholly stopping.

the motion of the denser, and destroying the reflection, (PROP. IV.) while they themselves will be more strongly propelled than if they had been at rest; and the transmitted light will be increased. So that the colours by reflection will be destroyed, and those by transmission rendered more vivid, when the double thicknesses, or intervals of retardation, are any multiples of the whole breadths of the undulations; and, at intermediate thicknesses the effects will be reversed; according to the NEWTONIAN observations.

If the same proportions be found to hold good with respect to thin plates of a denser medium, which is indeed not improbable, it will be necessary to adopt the corrected demonstration of PROP. IV. but, at any rate, if a thin plate be interposed between a rarer and a denser medium, the colours by reflection and transmission may be expected to change places.

From NEWTON's measures of the thicknesses reflecting the different colours, the breadth and duration of their respective undulations may be very accurately determined; although it is not improbable, that when the glasses approach very near, the atmosphere of ether may produce some little irregularity. The whole visible spectrum appears to be comprised within the ratio of three to five, or a major sixth in music; and the undulations of red, yellow, and blue, to be related in magnitude as the numbers 8, 7, and 6; so that the interval from red to blue is a fourth. The absolute frequency expressed in numbers is too great to be distinctly conceived, but it may be better imagined by a comparison with sound. If a chord sounding the tenor  $\overline{c}$ , could be continually bisected 40 times, and should then vibrate, it would afford a yellow green light: this being denoted by  $\overset{41}{c}$ , the extreme red would be  $\overset{40}{a}$ , and the blue  $\overset{41}{d}$ .

The absolute length and frequency of each vibration is expressed in the table; supposing light to travel in  $8\frac{1}{2}$  minutes 500,000,000,000 feet.

Colours.	Length of an Undulation in parts of an Inch, in Air.	Number of Undulations in an Inch.	Number of Undulations in a Second.
Extreme -	.0000266	37640	463 millions of millions
Red - -	.0000256	39180	482
Intermediate -	.0000246	40720	501
Orange - -	.0000240	41610	512
Intermediate -	.0000235	42510	523
Yellow - -	.0000227	44000	542
Intermediate -	.0000219	45600	561 (= $2^{48}$ nearly)
Green - -	.0000211	47460	584
Intermediate -	.0000203	49320	607
Blue - -	.0000196	51110	629
Intermediate -	.0000189	52910	652
Indigo - -	.0000185	54070	665
Intermediate -	.0000181	55240	680
Violet - -	.0000174	57490	707
Extreme - -	.0000167	59750	735

*Scholium.* It was not till I had satisfied myself respecting all these phenomena, that I found in HOOKE's Micrographia, a passage which might have led me earlier to a similar conclusion.  
 " It is most evident that the reflection from the under or further side of the body, is the principal cause of the production  
 " of these colours. — Let the ray fall obliquely on the thin  
 " plate, part therefore is reflected back by the first superficies,  
 " —part refracted to the second surface,—whence it is reflected  
 " and refracted again.—So that, after two refractions and one

“reflection, there is propagated a kind of fainter ray—,” and, “by reason of the time spent in passing and repassing,—this “fainter pulse comes behind the” former reflected “pulse; so “that hereby, (the surfaces being so near together that the eye “cannot discriminate them from one,) this confused or duplicated “pulse, whose strongest part precedes, and whose weakest fol-“lows, does produce on the retina, the sensation of a yellow. “If these surfaces are further removed asunder, the weaker “pulse may become coincident with the” reflection of the “second,” or next following pulse, from the first surface, “and “lag behind that also, and be coincident with the third, “fourth, fifth, sixth, seventh, or eighth—; so that, if there be “a thin transparent body, that from the greatest thinness requi-“site to produce colours, does by degrees grow to the greatest “thickness,—the colours shall be so often repeated, as the “weaker pulse does lose paces with its primary or first pulse, “and is coincident with a” subsequent “pulse. And this, as “it is coincident, or follows from the first hypothesis I took of “colours, so upon experiment have I found it in multitudes of “instances that seem to prove it.” (P. 65—67.) This was printed about seven years before any of NEWTON’s experiments were made. We are informed by NEWTON, that HOOKE was afterwards disposed to adopt his “suggestion” of the nature of colours; and yet it does not appear that HOOKE ever applied that improvement to his explanation of these phenomena, or inquired into the necessary consequence of a change of obliquity, upon his original supposition, otherwise he could not but have discovered a striking coincidence with the measures laid down by NEWTON from experiment. All former attempts to explain the colours of thin plates, have either proceeded on suppositions

which, like NEWTON's, would lead us to expect the greatest irregularities in the direction of the refracted rays; or, like Mr. MICHELL's, would require such effects from the change of the angle of incidence, as are contrary to the effects observed; or they are equally deficient with respect to both these circumstances, and are inconsistent with the most moderate attention to the principal phenomena.

*COROLLARY III. Of the Colours of thick Plates.*

When a beam of light passes through a refracting surface, especially if imperfectly polished, a portion of it is irregularly scattered, and makes the surface visible in all directions, but most conspicuously in directions not far distant from that of the light itself: and, if a reflecting surface be placed parallel to the refracting surface, this scattered light, as well as the principal beam, will be reflected, and there will also be a new dissipation of light, at the return of the beam through the refracting surface. These two portions of scattered light will coincide in direction; and, if the surfaces be of such a form as to collect the similar effects, will exhibit rings of colours. The interval of retardation is here, the difference between the paths of the principal beam and of the scattered light between the two surfaces; of course, wherever the inclination of the scattered light is equal to that of the beam, although in different planes, the interval will vanish, and all the undulations will conspire. At other inclinations, the interval will be the difference of the secants from the secant of the inclination or angle of refraction of the principal beam. From these causes, all the colours of concave mirrors observed by NEWTON and others are necessary consequences: and it appears that their production, though

somewhat similar, is by no means, as NEWTON imagined, identical with the production of those of thin plates.

#### COROLLARY IV. *Of Blackness.*

In the three preceding corollaries, we have considered the refracting and reflecting substances as limited by a mathematical surface; but this is perhaps never physically true. The ethereal atmospheres may extend on each side the surface as far as the breadth of one or more undulations; and, if they be supposed to vary equally in density at every part, the partial reflections from each of the infinite number of surfaces, where the density changes, will very much interfere with each other, and destroy a considerable portion of the reflected light, so that the substance may become positively black; and this effect may take place in a greater or less degree, as the density of the ethereal atmosphere varies more or less equably; and, in some cases, particular undulations being more affected than others, a tinge of colour may be produced. Accordingly, M. BOUGUER has observed a considerable loss of light, and in some instances a tinge of colour, in total reflections at the surface of a rarer medium.

#### COROLLARY V. *Of Colours by Inflection.*

Whatever may be the cause of the inflection of light passing through a small aperture, the light nearest its centre must be the least diverted, and the nearest to its sides the most: another portion of light falling very obliquely on the margin of the aperture, will be copiously reflected in various directions; some of which will either perfectly or very nearly coincide in direction with the unreflected light, and, having taken a circuitous

route, will so interfere with it, as to cause an appearance of colours. The length of the two tracks will differ the less, as the direction of the reflected light has been less changed by its reflection, that is, in the light passing nearest to the margin; so that the blues will appear in the light nearest the shadow. The effect will be increased and modified, when the reflected light falls within the influence of the opposite edge, so as to interfere with the light simply inflected by that also.

But, in order to examine the consequences more minutely, it will be convenient to suppose the inflection caused by an ethereal atmosphere, of a density varying as a given power of the distance from a centre, as in the eighth proposition of the last BAKERIAN Lecture. (Phil. Trans. for 1801, p. 83.) Putting  $r=3$ , and  $x=\frac{1}{2}$ , I have constructed a diagram, (Fig. 4,) which shows, by the two pairs of curves, the relative position of the reflected and unreflected portions of any one undulation at two successive times, and also, by shaded lines drawn across, the parts where the intervals of retardation are in arithmetical progression, and where similar colours will be exhibited at different distances from the inflecting substance. The result fully agrees with the observations of NEWTON's third book, and with those of later writers. But I do not consider it as quite certain, until further experiments have been made on the inflecting power of different substances, that Dr. HOOKE's explanation of inflection, by the tendency of light to diverge, may not have some pretensions to truth. I am sorry to be obliged to recall here the assent which, at first sight, I was induced to give to a supposed improvement of a late author. (Phil. Trans. for 1800, p. 128.)

*Scholium.* In the construction of the diagram, it becomes necessary to find the time spent by each ray in its passage.

Since the velocity was denoted by  $x^{-\frac{1}{r}}$ , on the supposition of a projectile, it will be as  $x^{\frac{1}{r}}$  on the contrary supposition, (Phil. Trans. for 1801, p. 27. Schol. 2. Prop. I.) and the fluxion of the

distance described being  $\frac{x}{\sqrt{1-yy}}$ , that of the time will be  $\frac{x^{-\frac{1}{r}}\dot{x}}{\sqrt{1-yy}}$ , or  $\frac{rs}{r-r}\cdot\frac{\dot{y}}{yy\cdot\sqrt{1-yy}}$ , of which the fluent is  $\frac{r}{r-r}\cdot\frac{s}{y}\cdot\sqrt{1-yy}$ .

Therefore, with the radius  $x^{1-\frac{1}{r}}$ , describe a circle concentric with the surfaces of the inflecting atmosphere, then the angle described by the ray during its passage through the atmosphere, will always be to the angle subtended by the line cut off by this circle from the incident ray produced, in the ratio of  $r$  to  $r-1$ ; and the time spent in this passage, will be in the same ratio to the time that would have been spent in describing this intercepted portion with the initial velocity. For  $y$ , being equal to  $sx^{\frac{1}{r}-1}$ , is the sine of the inclination of the incident ray to the radius, where it meets this circle; therefore, by the proposition quoted, the angle described is in a given ratio to the angle at the centre, which is the difference of the inclinations. Making  $x^{1-\frac{1}{r}}$  or  $\frac{s}{y}$  radius, the sine, instead of  $y$ , becomes  $s$ , and the cosine  $\sqrt{\frac{ss}{yy}-ss}$ , or  $\frac{s}{y}\sqrt{1-yy}$ , and, when  $y=ss$ ,  $\sqrt{1-ss}$ ; therefore the line intercepted is to the difference of the fluents as  $r$  to  $r-1$ . (See also YOUNG's Syllabus, Art. 372.)

#### PROPOSITION IX.

*Radiant Light consists in Undulations of the luminiferous Ether.*

This proposition is the general conclusion from all the preceding; and it is conceived that they conspire to prove it in as satisfactory a manner as can possibly be expected from the

nature of the subject. It is clearly granted by NEWTON, that there are undulations, yet he denies that they constitute light; but it is shown in the three first Corollaries of the last Proposition, that all cases of the increase or diminution of light are referable to an increase or diminution of such undulations, and that all the affections to which the undulations would be liable, are distinctly visible in the phenomena of light; it may therefore be very logically inferred, that the undulations are light.

A few detached remarks will serve to obviate some objections which may be raised against this theory.

1. NEWTON has advanced the singular refraction of the Iceland crystal, as an argument that the particles of light must be projected corpuscles; since he thinks it probable that the different sides of these particles must be differently attracted by the crystal, and since HUYGENS has confessed his inability to account in a satisfactory manner for all the phenomena. But, contrarily to what might have been expected from NEWTON's usual accuracy and candour, he has laid down a new law for the refraction, without giving a reason for rejecting that of HUYGENS, which Mr. HAUV has found to be more accurate than NEWTON's; and, without attempting to deduce from his own system any explanation of the more universal and striking effects of doubling spars, he has omitted to observe that HUYGENS's most elegant and ingenious theory perfectly accords with these general effects, in all particulars, and of course derives from them additional pretensions to truth: this he omits, in order to point out a difficulty, for which only a verbal solution can be found in his own theory, and which will probably long remain unexplained by any other.

2. Mr. MICHELL has made some experiments, which appear to show that the rays of light have an actual momentum, by

means of which a motion is produced when they fall on a thin plate of copper delicately suspended. (PRIESTLEY's Optics.) But, taking for granted the exact perpendicularity of the plate, and the absence of any ascending current of air, yet since, in every such experiment, a greater quantity of heat must be communicated to the air at the surface on which the light falls than at the opposite surface, the excess of expansion must necessarily produce an excess of pressure on the first surface, and a very perceptible recession of the plate in the direction of the light. Mr. BENNET has repeated the experiment, with a much more sensible apparatus, and also in the absence of air; and very justly infers from its total failure, an argument in favour of the undulatory system of light. (Phil. Trans. for 1792, p. 87.) For, granting the utmost imaginable subtlety of the corpuscles of light, their effects might naturally be expected to bear some proportion to the effects of the much less rapid motions of the electrical fluid, which are so very easily perceptible, even in their weakest states.

3. There are some phenomena of the light of solar phosphori, which at first sight might seem to favour the corpuscular system; for instance, its remaining many months as if in a latent state, and its subsequent re-emission by the action of heat. But, on further consideration, there is no difficulty in supposing the particles of the phosphori which have been made to vibrate by the action of light, to have this action abruptly suspended by the intervention of cold, whether as contracting the bulk of the substance or otherwise; and again, after the restraint is removed, to proceed in their motion, as a spring would do which had been held fast for a time in an intermediate stage of its vibration; nor is it impossible that heat itself may, in some circumstances, become in a similar manner latent. (NICHOLSON's

Journal. Vol. II. p. 399.) But the affections of heat may perhaps hereafter be rendered more intelligible to us; at present, it seems highly probable that light differs from heat only in the frequency of its undulations or vibrations; those undulations which are within certain limits, with respect to frequency, being capable of affecting the optic nerve, and constituting light; and those which are slower, and probably stronger, constituting heat only; that light and heat occur to us, each in two predicaments, the vibratory or permanent, and the undulatory or transient state; vibratory light being the minute motion of ignited bodies, or of solar phosphori, and undulatory or radiant light the motion of the ethereal medium excited by these vibrations; vibratory heat being a motion to which all material substances are liable, and which is more or less permanent; and undulatory heat that motion of the same ethereal medium, which has been shown by Mr. KING, (Morsels of Criticism. 1786. p. 99,) and M. PICTET, (*Essais de Physique*. 1790,) to be as capable of reflection as light, and by Dr. HERSCHEL to be capable of separate refraction. (Phil. Trans. for 1800. p. 284.) How much more readily heat is communicated by the free access of colder substances, than either by radiation or by transmission through a quiescent medium, has been shown by the valuable experiments of Count RUMFORD. It is easy to conceive that some substances, permeable to light, may be unfit for the transmission of heat, in the same manner as particular substances may transmit some kinds of light, while they are opaque with respect to others.

On the whole it appears, that the few optical phenomena which admit of explanation by the corpuscular system, are equally consistent with this theory; that many others, which have long been known, but never understood, become by these means perfectly intelligible; and that several new facts are

found to be thus only reducible to a perfect analogy with other facts, and to the simple principles of the undulatory system. It is presumed, that henceforth the second and third books of NEWTON's Optics will be considered as more fully understood than the first has hitherto been ; but, if it should appear to impartial judges, that additional evidence is wanting for the establishment of the theory, it will be easy to enter more minutely into the details of various experiments, and to show the insuperable difficulties attending the NEWTONIAN doctrines, which, without necessity, it would be tedious and invidious to enumerate. The merits of their author in natural philosophy, are great beyond all contest or comparison ; his optical discovery of the composition of white light, would alone have immortalised his name ; and the very arguments which tend to overthrow his system, give the strongest proofs of the admirable accuracy of his experiments.

Sufficient and decisive as these arguments appear, it cannot be superfluous to seek for further confirmation; which may with considerable confidence be expected, from an experiment very ingeniously suggested by Professor ROBISON, on the refraction of the light returning to us from the opposite margins of Saturn's ring; for, on the corpuscular theory, the ring must be considerably distorted when viewed through an achromatic prism : a similar distortion ought also to be observed in the disc of Jupiter; but, if it be found that an equal deviation is produced in the whole light reflected from these planets, there can scarcely be any remaining hope to explain the affections of light, by a comparison with the motions of projectiles.









































































